

**WHAT IS CLAIMED IS:**

1. A method of calculating a linear minimum convolution of a weight value  $\alpha$  with a continuous piecewise linear function L including a plurality of line segments connected at knot points, the method comprising:

performing a forward leg sweep over the function L in a first direction with a clipping function comprised of a knot point connecting a first leg of slope  $\alpha$  and a second leg of slope  $-\alpha$ ; and  
performing a backward leg sweep over the function L in a second direction with the clipping function.

2. The method of claim 1 wherein the performing the forward leg sweep comprises:

selecting a first point of the knot points of the function L as a current point;  
removing a portion of the function L if the first leg is determined to clip said portion of the function L;  
selecting a next point in the first direction of the knot points of the function L as the current point; and  
repeating the determining and the selecting the next point until the determining has been performed for all knot points of the function L.

3. The method of claim 2 wherein the removing the portion of the function L comprises:

finding an intersection point of the function L in the first direction from the current point at which the first leg intersects the function L;  
discarding all knot points between the current point and the intersection point from a list of knot points of the function L; and  
inserting the intersection point into the list of knot points of the function L;  
and wherein  
the selecting the next point begins with the intersection point as the current point.

4. The method of claim 2 wherein the first leg is determined to clip said portion of the function L if the absolute value of the slope of the function L is greater than the absolute value of  $\alpha$  at all points of said portion of the function L.

5. The method of claim 2 wherein the first leg is determined to clip said portion of the function L if the value of the function L at all points of said portion are less than the value of the clipping function.

6. The method of claim 1 wherein the performing the backward leg sweep comprises:

selecting a first point of the knot points of the function L as a current point;  
removing a portion of the function L if the second leg is determined to clip said portion of the function L;  
selecting a next point in the second direction of the knot points of the function as the current point; and  
repeating the determining and the selecting the next point until the determining has been performed for all knot points of the function L.

7. The method of claim 6 wherein the removing the portion of the function L comprises:

finding an intersection point of the function L in the second direction from the current point at which the second leg intersects the function L;  
discarding all knot points between the current point and the intersection point from a list of knot points of the function L; and  
inserting the intersection point into the list of knot points of the function L;  
and wherein  
the selecting the next point begins with the intersection point as the current point.

8. The method of claim 2 wherein the a list of knot points of the function L is unaffected each time the second leg is determined not to clip a portion of the function L.

9. The method of claim 1 wherein the performing the forward leg sweep comprises:

setting an index pointer  $p$  to an initial value corresponding to a first end of the function  $L$ ;

scanning line segments of the function  $L$  in a first direction from a first end line segment  $l_p$  towards a second end line segment to determine a line segment  $l_j$  having a slope greater than the weight  $\alpha$ ;

defining a forward leg  $g(x) = \alpha(x-a_j) + L(a_j)$  where  $a_j$  is an x-location on the line segment  $l_j$ ;

if a line segment  $l_j$  is found, scanning in the first direction from the line segment  $l_j$  and removing line segments from the function  $L$  until an intersecting line segment  $l_i$  of the function  $L$  intersects the forward leg;

if an intersecting line segment  $l_i$  is encountered,

inserting a new segment  $g(x) = \alpha(x-a_j) + L(a_j)$  in place of the first removed line segment  $l_j$ , wherein the new segment  $g(x)$  is defined from intersecting point  $a_j$  to the intersection point  $a_i$ ;

inserting a new segment from the intersection point  $a_i$  to the first direction end point of  $l_i$ ;

incrementing  $p$  by two; and

repeating the above steps except the step of setting the index pointer  $p$  to the initial value; and

if an intersecting line segment  $l_i$  is not encountered, inserting a new segment  $g(x)$  in place of the first removed line segment  $l_j$ , wherein the new segment  $g(x)$  is defined from the first direction end of line segment  $l_j$  to the second end of the function  $L$ .

10. The method of claim 1 wherein the function  $L$  is a cost function for providing a cost of a path across a segment at various points along the segment.

11. The method of claim 10 further comprising:

providing the weight value  $\alpha$  to a processor module;

providing the cost function L to the processor module, wherein the cost function L is a source cost function providing a cost from a source to a segment;  
receiving from the processor module an output linear minimal convolution of the weight value  $\alpha$  and the cost function L.

12. The method of claim 11 wherein the weight value  $\alpha$  is a weight for a cost in a first direction; and the method further comprises using the output linear minimal convolution to calculate a clear path in at least the first direction from a first location to a second location.

13. The method of claim 12 wherein the first and second locations are in a routing area of an integrated circuit.

14. The method of claim 1 wherein the function L is a continuous piecewise linear function  $f(x)$  defined for points  $\lambda$  over an x-axis interval  $[a, b]$ ; and the linear minimum convolution  $(\alpha * f)(x)$  of the weight value  $\alpha$  with the function  $f(x)$  is defined as follows:

$$(\alpha * f)(x) = \min_{\lambda \in [a, b]} (f(\lambda) + \alpha |\lambda - x|)$$

15. A computer program product encoded in computer readable media for calculating a linear minimum convolution of a value with a function, the function including a plurality of line segments connected at knot points, the computer program product comprising:

a software module for performing a forward leg sweep over the function in a first direction with a clipping function comprised of a knot point connecting a first leg of a first slope and a second leg of a second slope, the second slope being a negative of the first slope; and a software module for performing a backward leg sweep over the function in a second direction with the clipping function.

first instructions, executable by an information processing system for selecting a first point of the knot points of the function as a current point;

second instructions, executable by an information processing system for determining if the first leg clips a portion of the function;

third instructions, executable by an information processing system for selecting a next point in the first direction of the knot points of the function as the current point; and

fourth instructions, executable by an information processing system for repeating the determining and the selecting the next point until the determining has been performed for all knot points of the function.

first instructions, executable by an information processing system for selecting a first point of the knot points of the function L as a current point;

second instructions, executable by an information processing system for determining if the second leg clips a portion of the function L;

third instructions, executable by an information processing system for selecting a next point in the second direction of the knot points of the function as the current point; and

fourth instructions, executable by an information processing system for repeating the determining and the selecting the next point until the determining has been performed for all knot points of the function L.

18. The product of claim 17 wherein some of the instructions of the software module for performing the forward leg sweep are also instructions of the software module for performing the backward leg sweep:

fifth instructions, executable by an information processing system if the first leg is determined to clip a portion of the function L, the first

instructions for finding an intersection point of the function L in the first direction from the current point at which the first leg intersects the function L;

sixth instructions, executable by an information processing system after the first instructions for finding the intersection point, the second instructions discarding all knot points between the current point and the intersection point from a list of knot points of the function L; and seventh instructions, executable by an information processing system after the second instructions for discarding knot points, the third instructions inserting the intersection point into the list of knot points of the function L; and wherein

the third instructions for selecting the next point first select the intersection point as the current point after the fifth instructions find the intersection point.

20. The product of claim 15 further comprising:

instructions for providing the weight value  $\alpha$  to a processor module;

instructions for providing the cost function L to the processor module, wherein the cost function L is a source cost function providing a cost from a source to a segment;

instructions for receiving from the processor module an output linear minimal convolution of the weight value  $\alpha$  and the cost function L.

21. The product of claim 20 further comprising:

instructions for using the output linear minimal convolution to calculate a clear path in at least the first direction from a first location to a second location.

22. The product of claim 15 wherein the product is for routing an integrated circuit design.

FOOTNOTES

23. The product of claim 15 wherein the computer readable media comprises at least one data storage medium, the at least one data storage medium including at least one of the group consisting of:

- magnetic disk media;
- magnetic tape storage media;
- compact disk storage media;
- digital video disk storage media; and
- nonvolatile memory.

24. The product of claim 15 wherein the computer readable media comprises at least one data transmission medium, the at least one data transmission medium including at least one of the group consisting of:

- a computer network;
- a point-to-point telecommunication system; and
- carrier wave transmission media.

25. An information processing system configured for calculating a linear minimum convolution of a weight value  $\alpha$  with a continuous piecewise linear function L including a plurality of line segments connected at knot points, the system comprising:

- at least one processor;
- a first module configured to be coupled to the processor for performing a forward leg sweep over the function L in a first direction with a clipping function comprised of a knot point connecting a first leg of slope  $\alpha$  and a second leg of slope  $-\alpha$ ; and
- a second module configured to be coupled to the processor for performing a backward leg sweep over the function L in a second direction with the clipping function.

26. The system of claim of claim 1 wherein the modules are software modules encoded on a data-storage computer readable medium coupled to the processor.

27. The system of claim of claim 1 wherein the system includes computer instructions used by both the first and second modules.